# Muon Collider Cavity Breakdown Progress

## Progress of High Pressure Hydrogen Gas Filled RF Cavity Test

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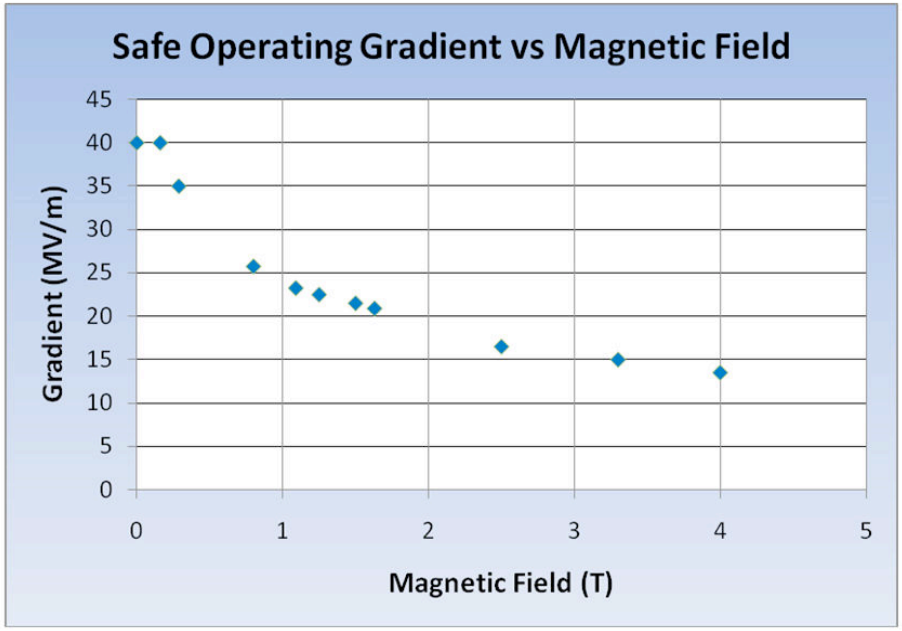
# Advantage of using high pressure hydrogen gas

## Challenge in MAP (Muon Accelerator Program) RF part

We have a problem to operate RF cavities under strong magnetic fields in muon ionization cooling channels

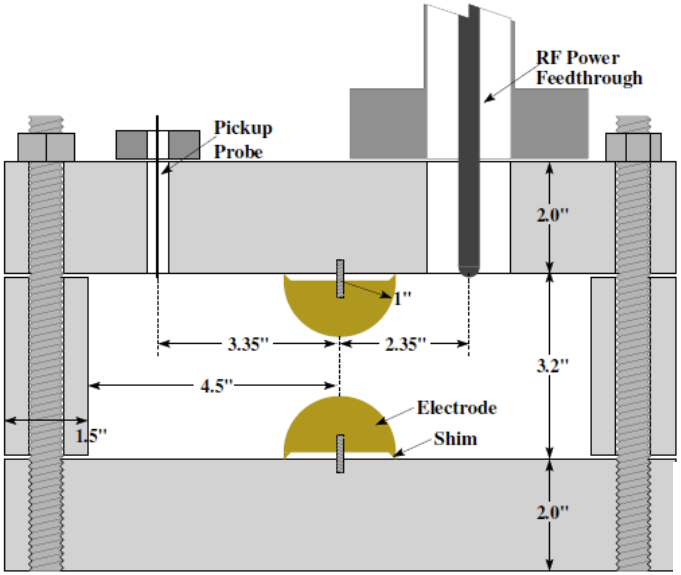



Field emission electron plays an important role to induce RF breakdown although the breakdown mechanism is not fully understood yet

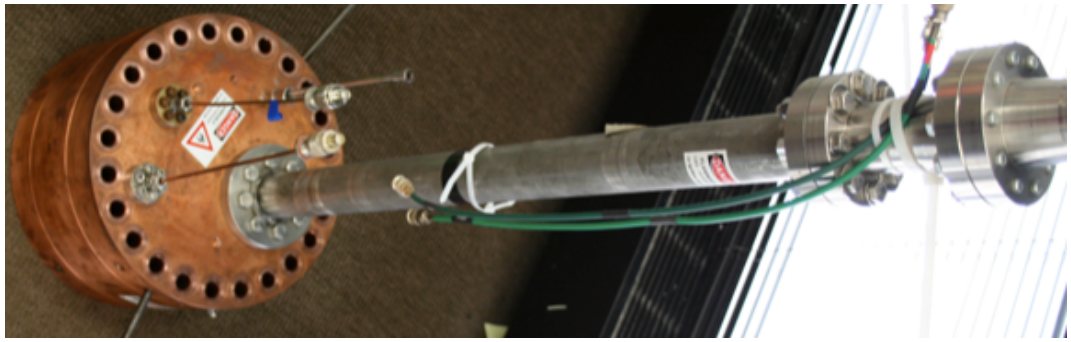
By filling RF cavity with dense hydrogen gas, field emission electron has a short mean free path in the cavity and breakdown probability is greatly reduced

R.P. Johnson and D.M. Kaplan, MuCoolNote0195, 2001

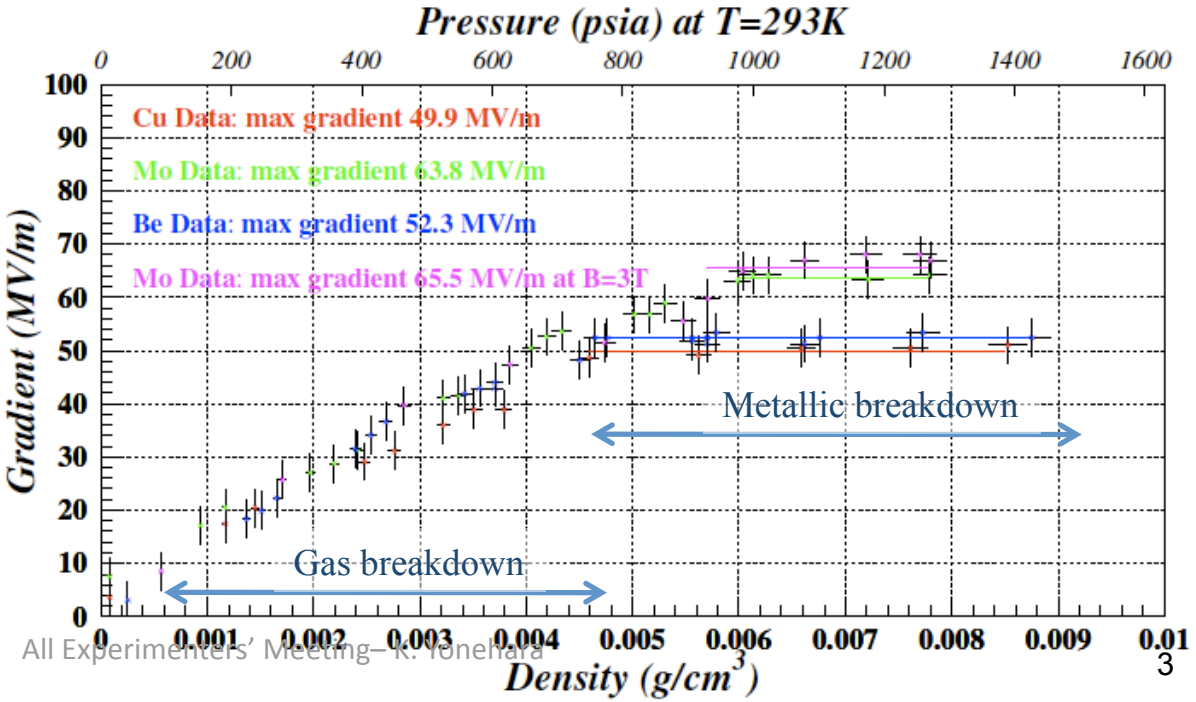
# Historic result in high pressure RF cavity




**Schematic view of HPRF cavity**



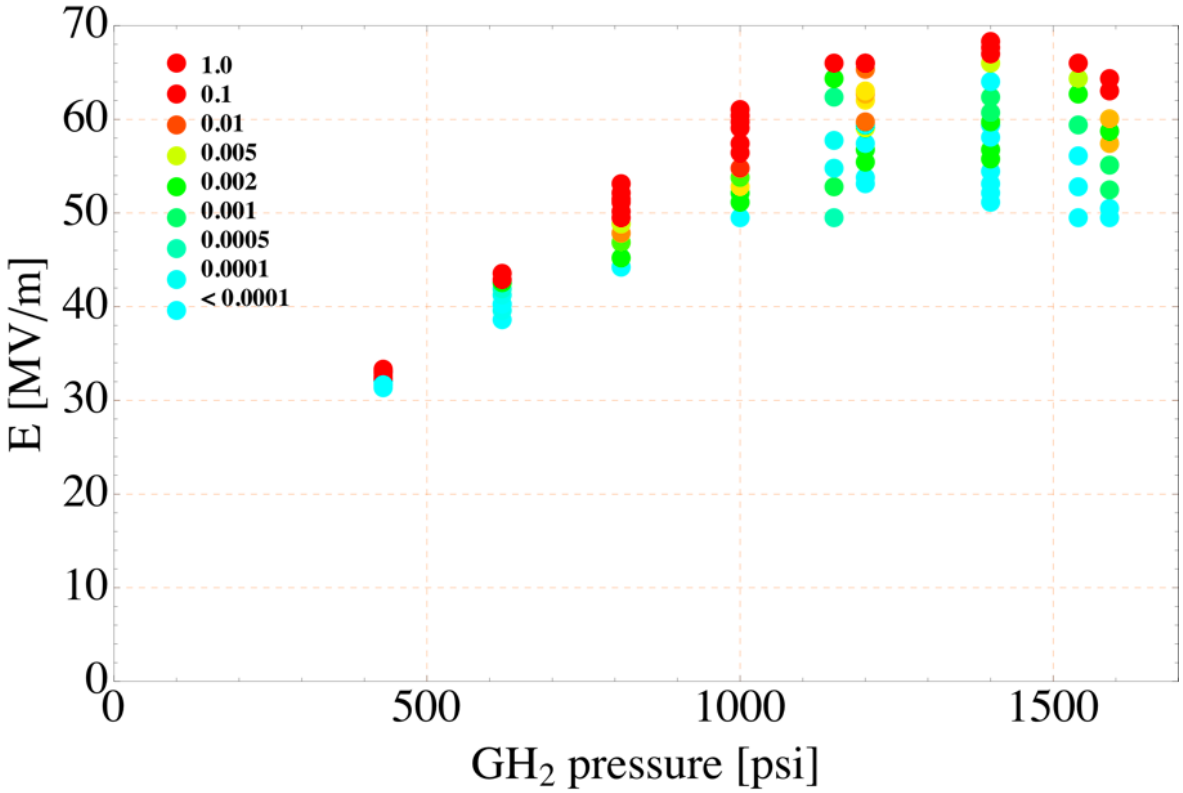
High Pressure RF (HPRF) cavity has been successfully operated in strong magnetic fields



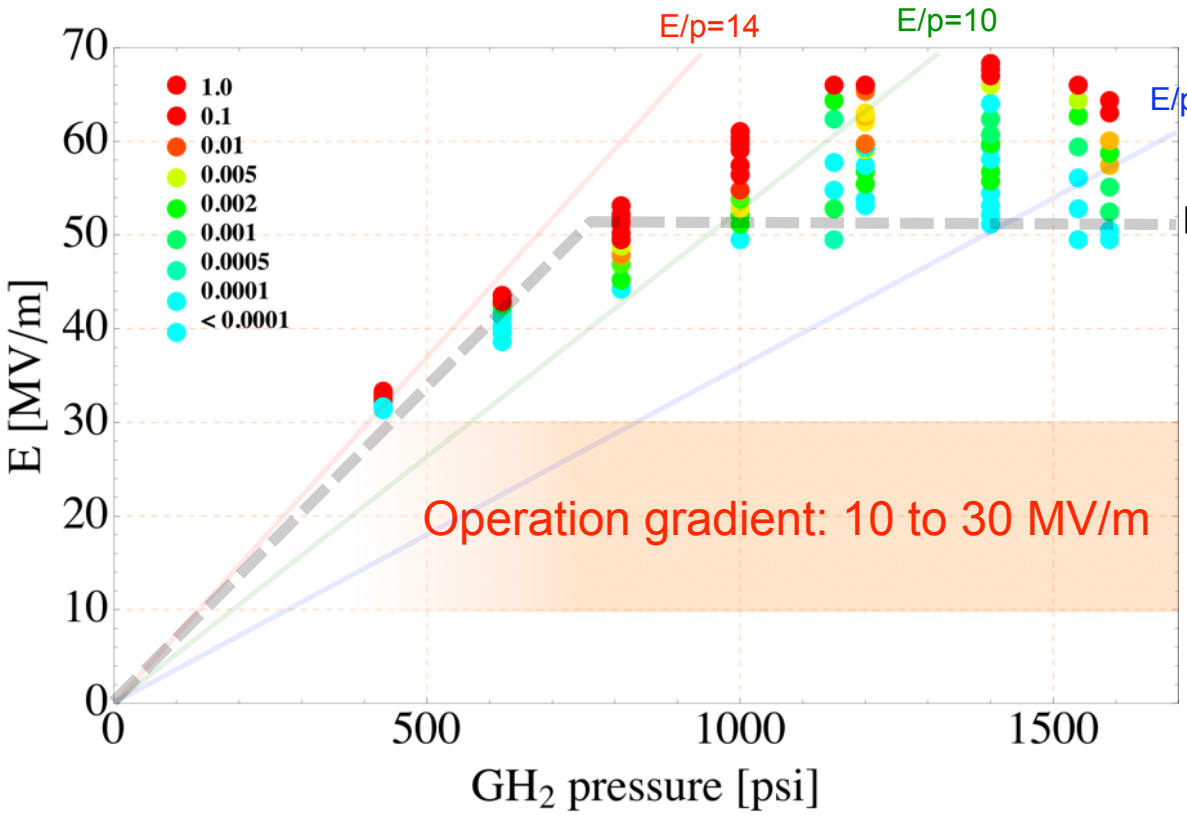

Gas breakdown:
- Linear dependence
- Governed by electron mean free path

Metallic breakdown:
- Plateau
- Depend on electrode material
- No detail study have been made yet

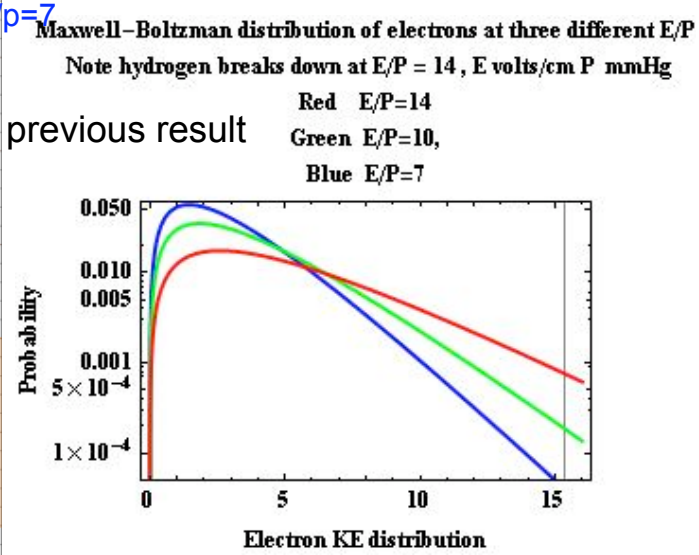
# Study breakdown in HPRF cavity: Breakdown probability




**Breakdown probability around boundary**
The data was systematically taken with copper electrodes




previous result



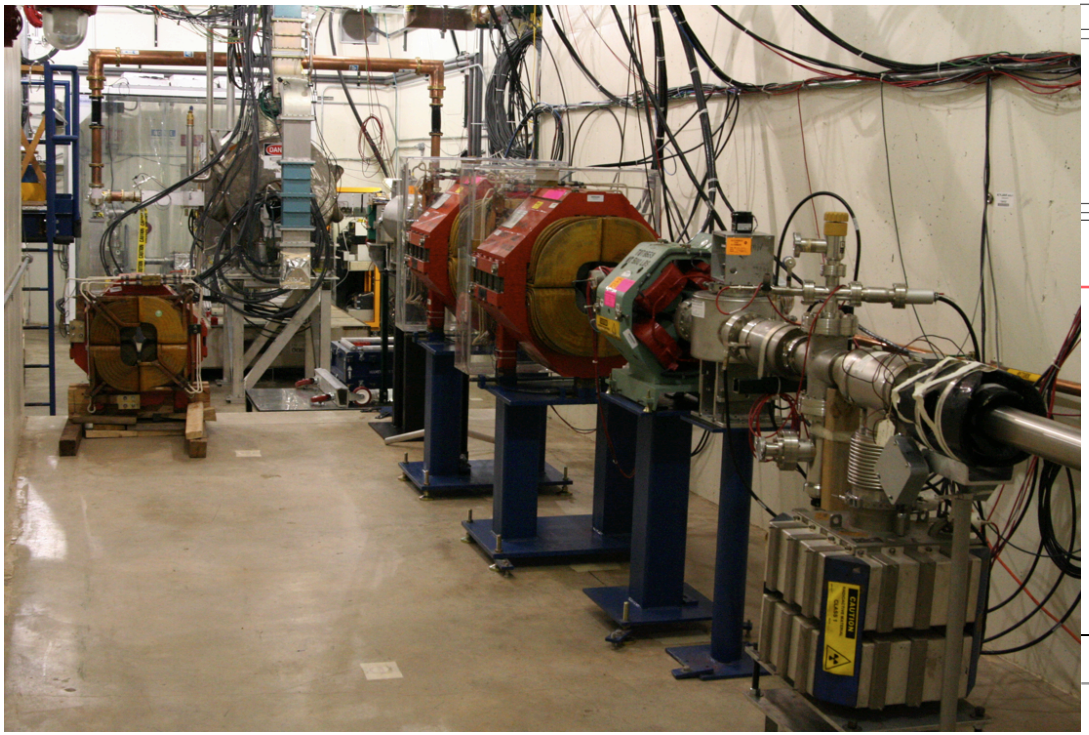

**Breakdown probability around boundary**

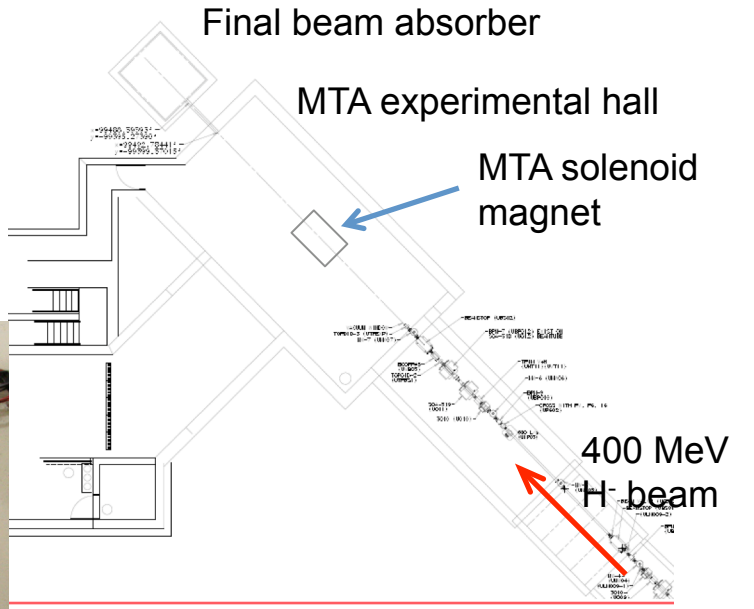
The data was systematically taken with copper electrodes

# HPRF beam test: MTA Beam line

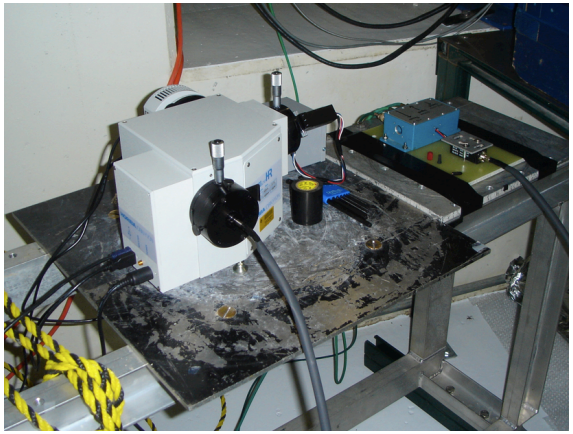
## Beam profile

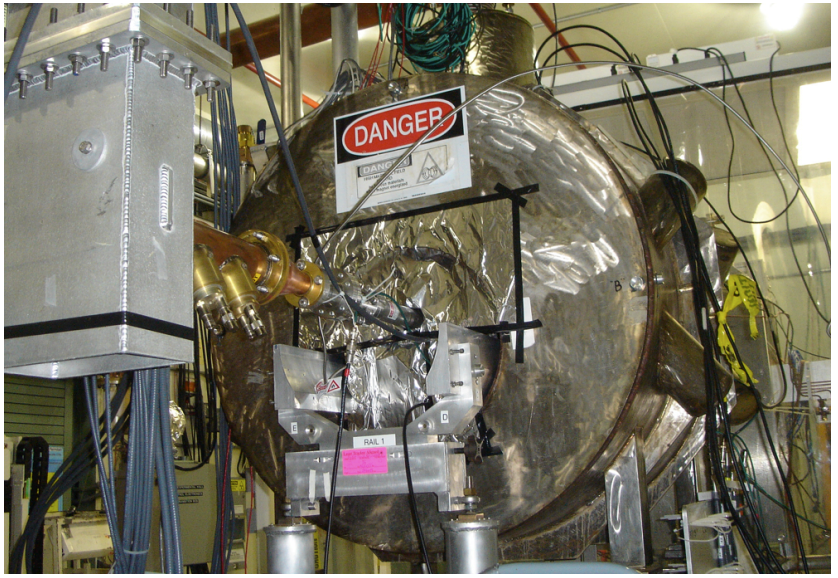
- Deliver 400 MeV protons in the MTA exp. hall
- $10^{12}$ to $10^{13}$ protons/pulse
- Tune beam intensity by collimator and triplet (reduce factor 1/10)

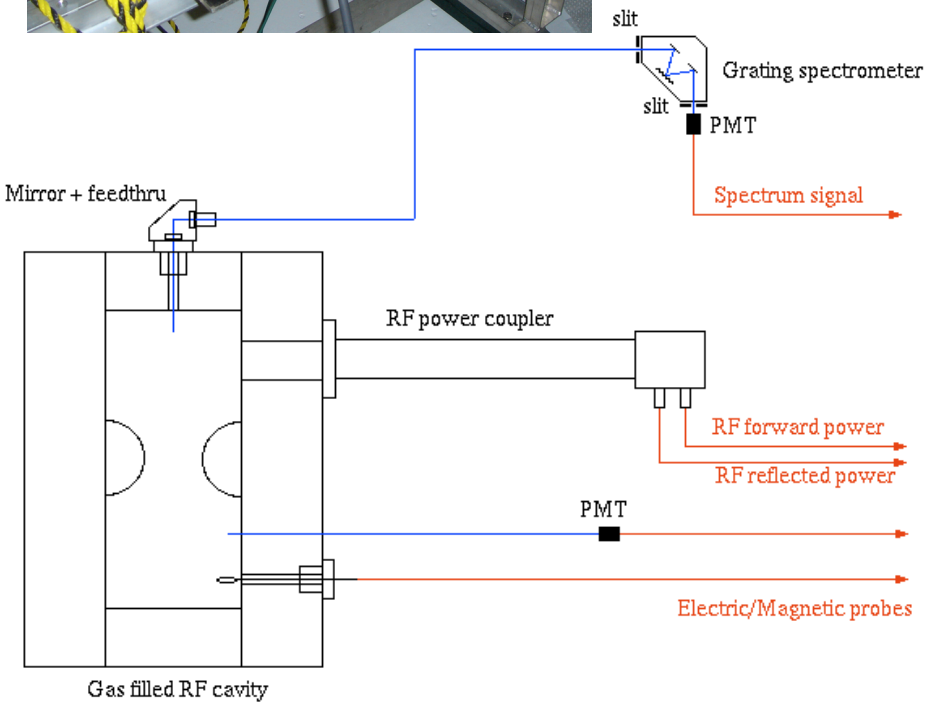


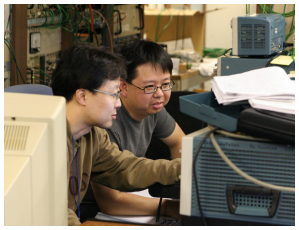


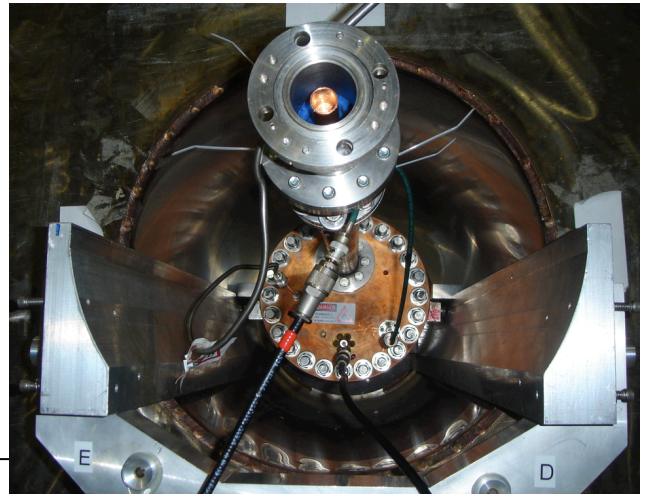
# Instrumentation



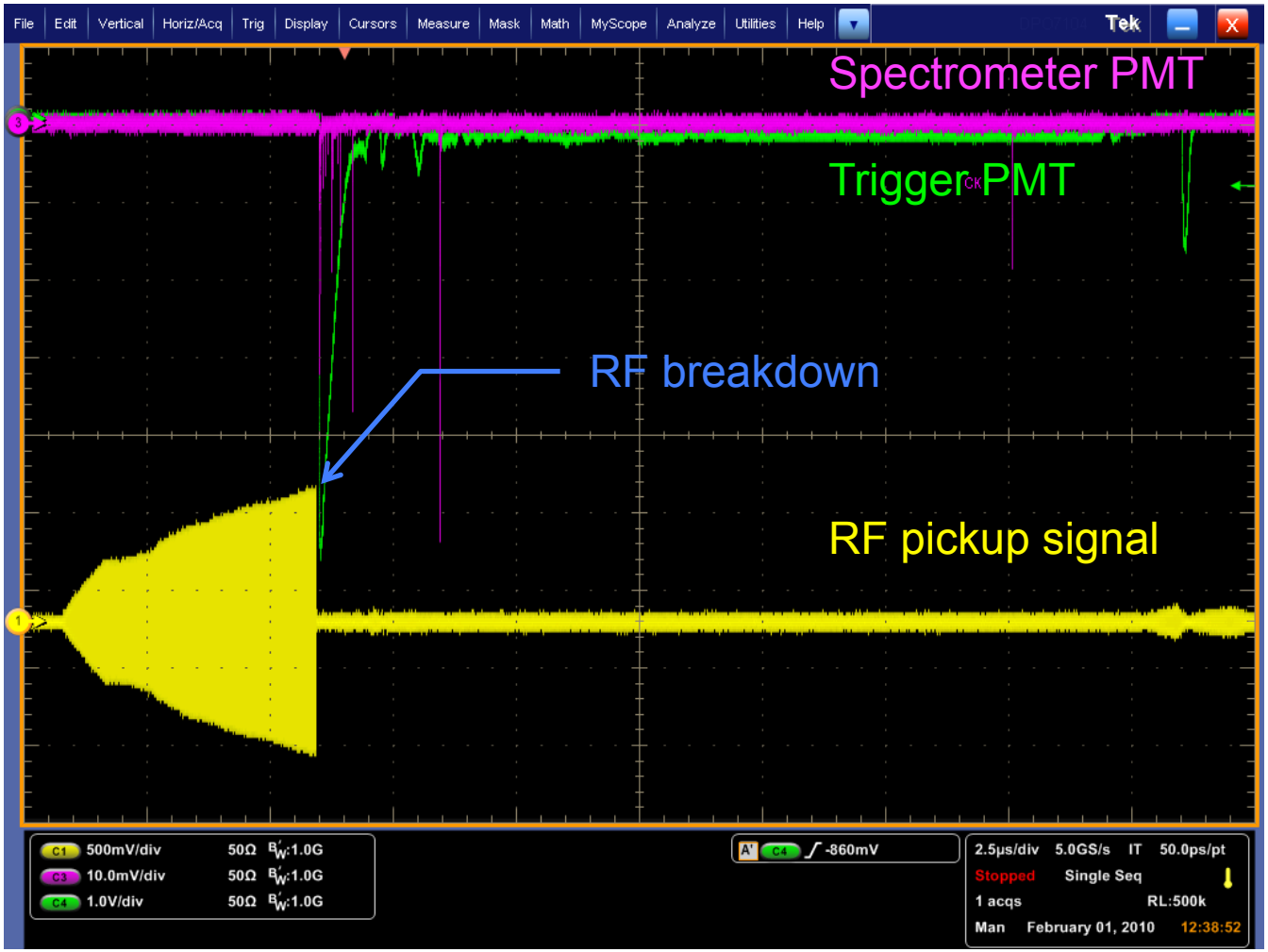


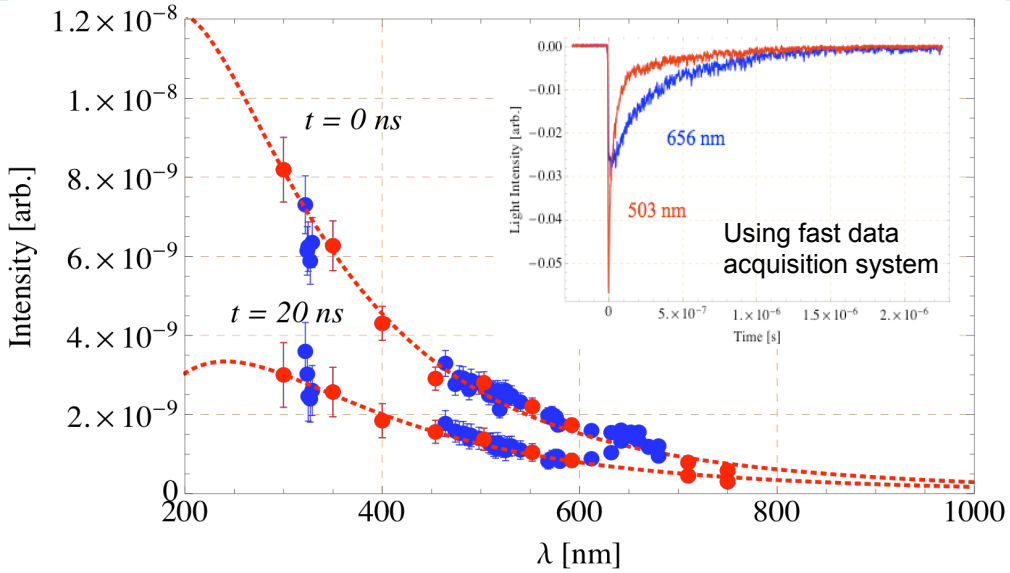





# Snapshot


File Edit Vertical Horiz/Acq Trig Display Cursors Measure Mask Math MyScope Analyze Utilities Help
Tek
Spectrometer PMT
Trigger PMT
RF breakdown
RF pickup signal
C1 500mV/div 50Ω BW:1.0G
C3 10.0mV/div 50Ω BW:1.0G
C4 1.0V/div 50Ω BW:1.0G
C4 -860mV
2.5µs/div 5.0GS/s IT 50.0ps/pt
Stopped Single Seq
1 acqs RL:500k
Man February 01, 2010 12:38:52

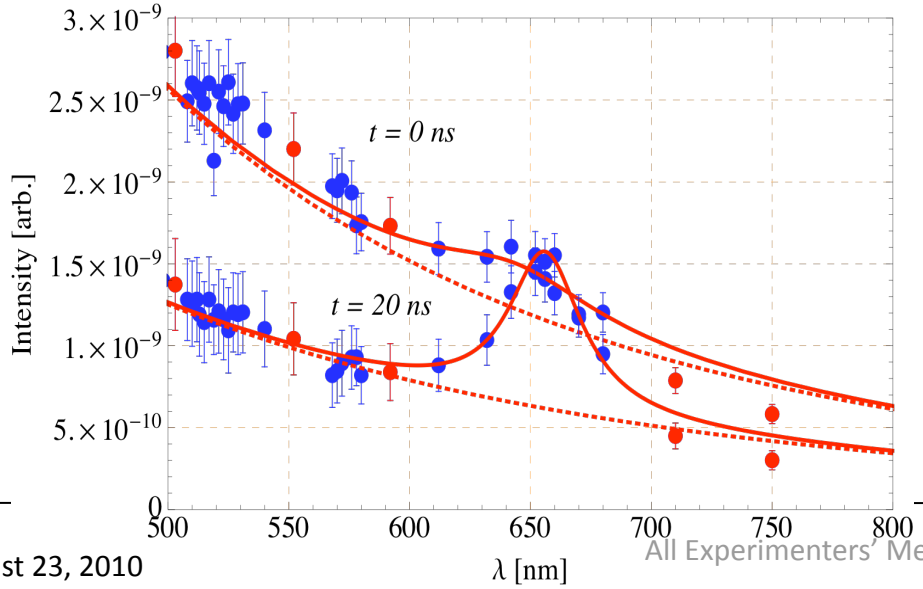
# Study hydrogen plasma dynamics: Spectroscopy of breakdown light




**Spectroscopy in the high pressure RF cavity**

## Thermal radiation:

- Broken line is a least square fitting of thermal radiation formula by taking into account red points which is on neither any hydrogen nor copper resonance lines
- "0 ns" is a peak light intensity

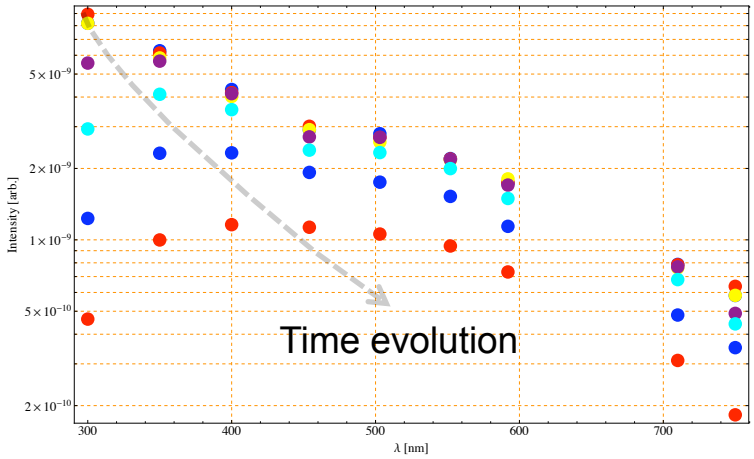



**Spectroscopy at Balmer line**

## Spontaneous emission:

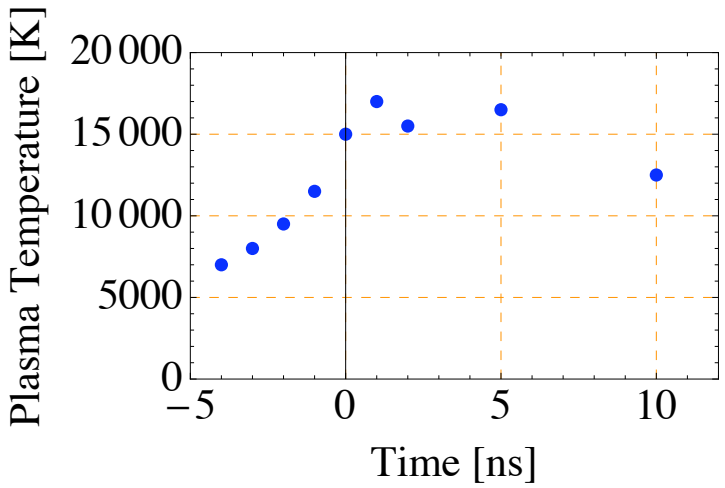
- Solid line is a least square fitting of Lorentz function by taking into account all points
- Timing delay due to lifetime of de-excitation
- Broadened Balmer line is observed
- Stark effect well-explains resonance broadening
- Plasma density $10^{18}$~$10^{19}$ electrons/cm$^3$

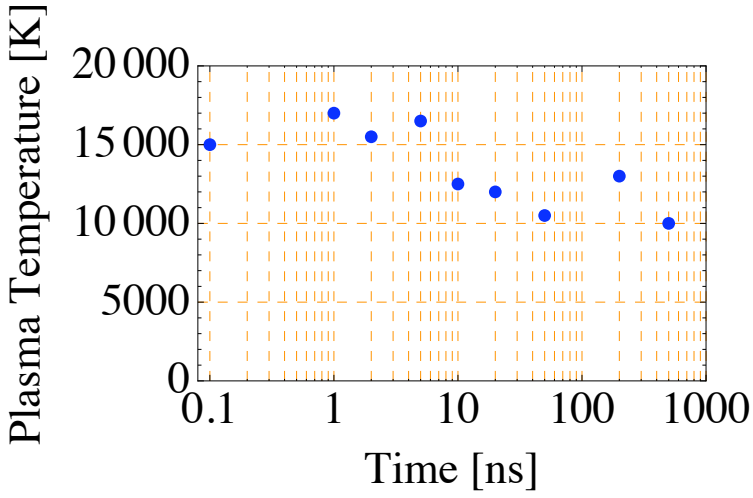
# Plasma temperature analysis




**Thermal radiation spectrum**

- Peak is shifted as a function of time



# Conclusion

- High pressure RF cavity is a potential element for muon ionization cooling channel
  - Successful HPRF cavity tests in strong magnetic fields have been done
  - Physics rich subject: Not only accelerator physics but also plasma & atomic physics topics are involved in R&D
- Beam test is scheduled to demonstrate HPRF cavity in high radiation condition
  - First 400 MeV proton beam test will be finished at the end of 2010
- Spectroscopy of breakdown has been done
  - Measure thermal radiation
    → Analyze plasma temperature
  - Observe broadened resonance light
    → Estimate plasma density